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Multi-Channel Phase Calibration Method for 5G Phased Array System

Cemin Zhang, PhD
Chengdu Sicore Semiconductor Ltd.

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Outlines

- 5G phased array – why phase accuracy is the key
- Analog phase shifters for 5G
- Challenges for Multi-channel phase calibration
- Proposed phase calibration method for 5G phased array
- Results and conclusions

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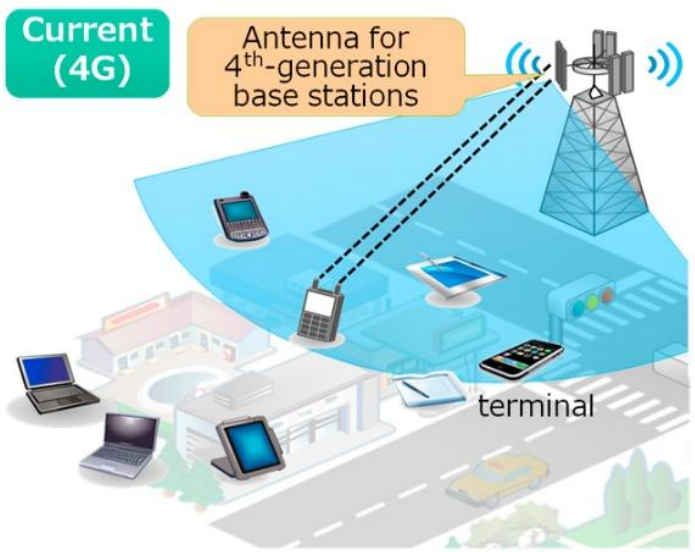
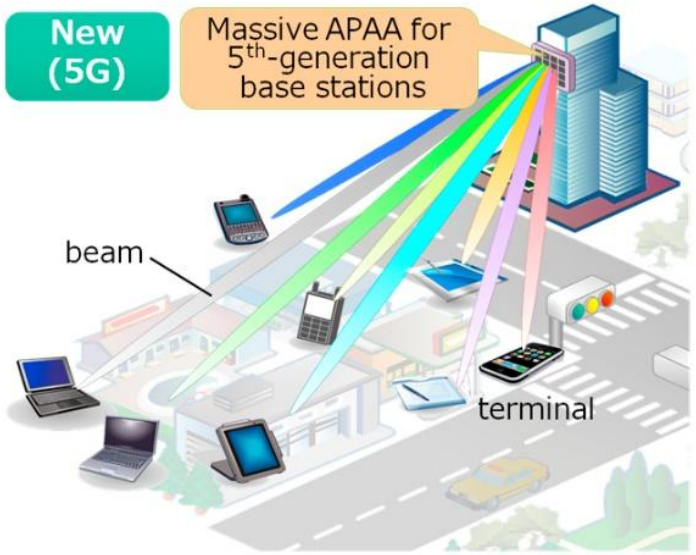
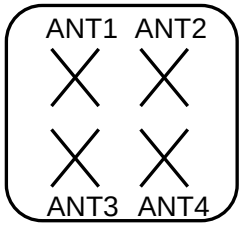
5G Beamforming and MIMO



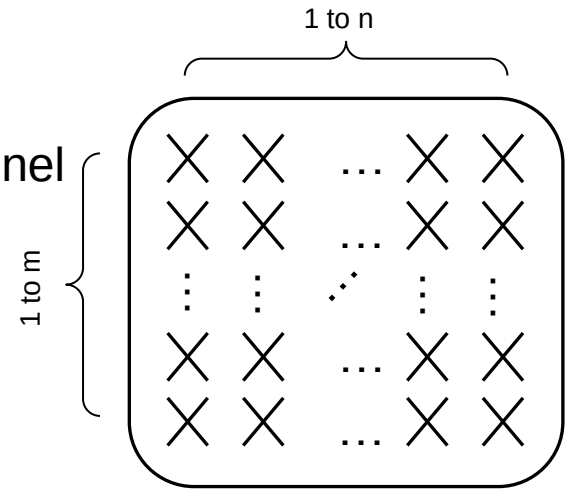


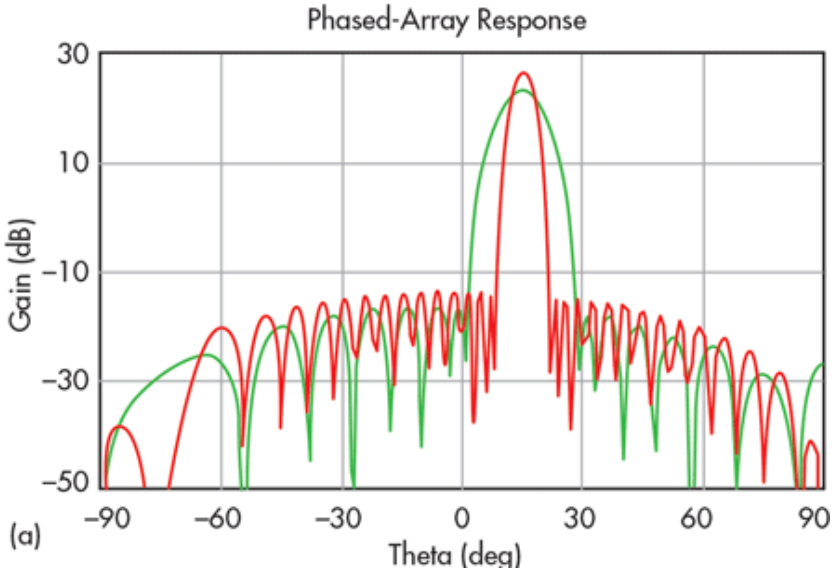
Phased Array 2x2 and mxn Channel

2 x 2 channel



m x n channel





- More channel/element means sharper beam and higher gain;
- Demands higher phase shift accuracy;
- Some 5G testbed, 128 x 128 array are proposed.

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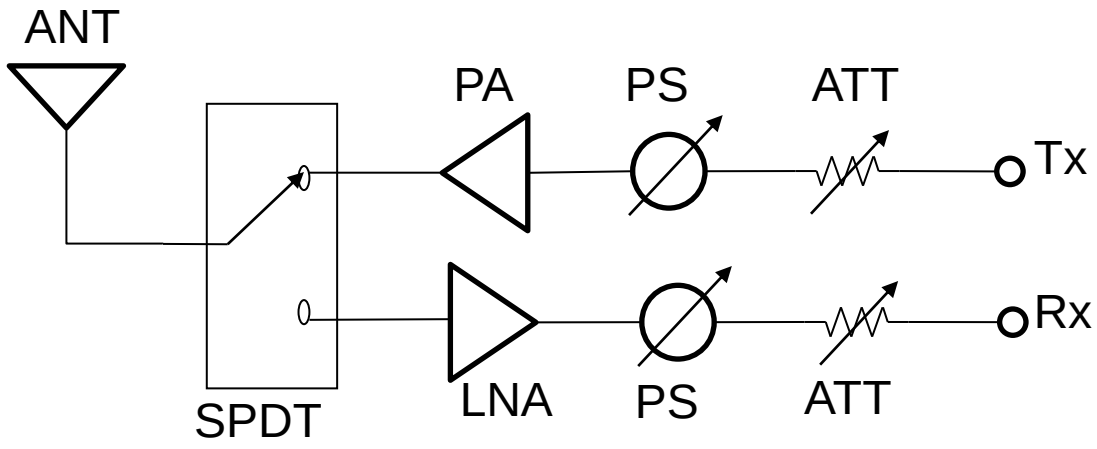
Phased Array Transceiver Architecture



- Key components: Phase shifter, Attenuator
- Key specs: Channel phase consistency, insertion loss

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Ideal multi-channel phased-array

A) Each channel, w. same control word:

- Identical phase shift amount
- Identical attenuation amount

B) Phase stays constant when attenuation state changes, and vice versa

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Actual multi-channel phased-array

A) Each channel, w. same control word:

- Phase shift amount non-identical
- Attenuation amount non-identical

B) Phase changes when attenuation state changes, and vice versa

Traditionally, need full calibration for each channel.

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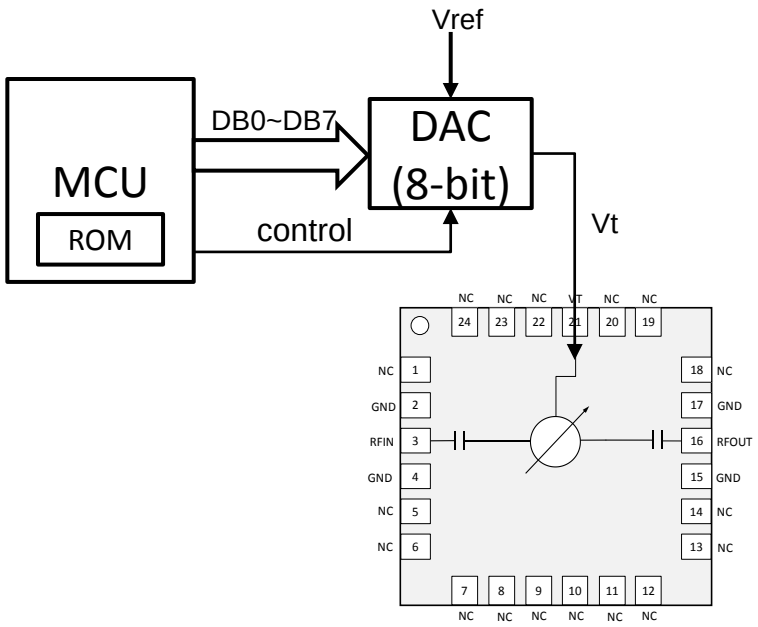
Phase Shifter – Analog vs. Digital

	Analog Phase Shifter	Digital Phase Shifter
Insertion Loss	Lower	Higher
Freq Bandwidth	Wide	Narrow
Phase Resolution	< 1° (limited by DAC)	5.625° (for 6bit)
Monotonic Response	Yes	No
Bias Requirement	Single positive voltage	Need negative bias
IP3	Lower	Higher
Multi-channel Phase Calibration Ready	Yes	No

Analog Phase Shifter Work w. DAC



- DB0~DB7: Digital control word from MCU
- Vref: ref voltage for DAC
- $Vt = D \bullet (Vref)$, for 8-bit DAC， D = 0 to 255/256.

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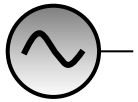
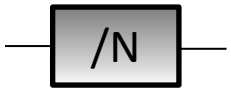
Sicore MMIC Product Lines

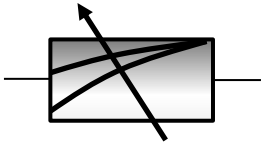


VCO

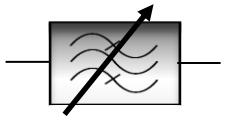


Freq Div

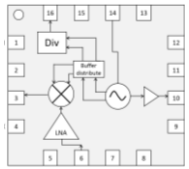
Phase Shifter



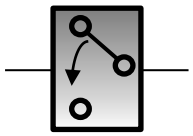
Equalizer



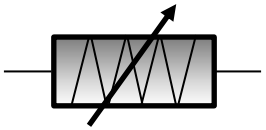
BPF



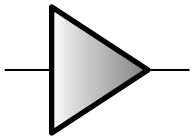
24G TRX



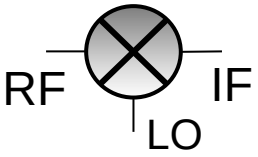
Switches



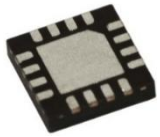
ATT

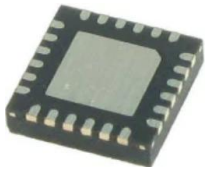


Amp

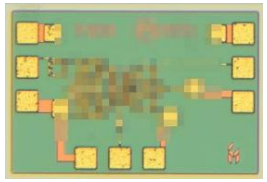


Mixers

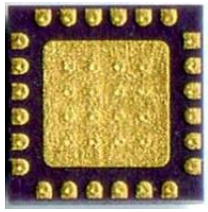




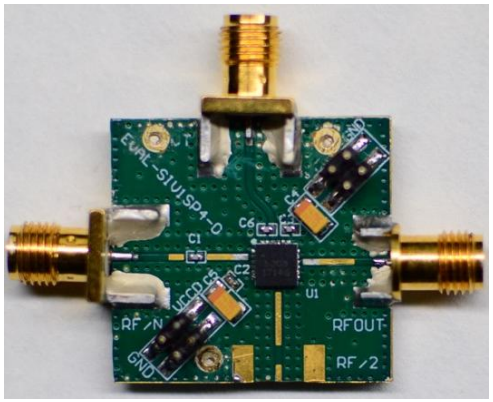
QFN Plastic

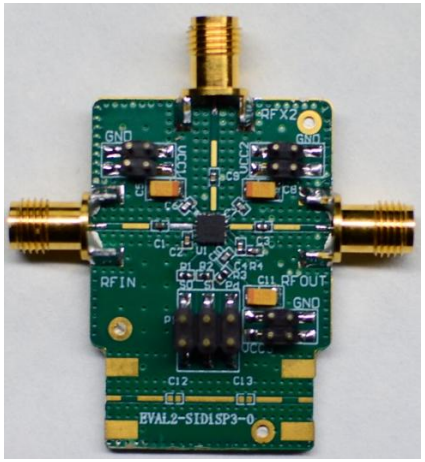


Die



QFN Ceramic





Evaluation Kits

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Sicore 5G Portfolio

5G移动通信类汇总

当前位置： 网站首页 - 产品中心 - 5G移动通信类汇总

型号	频段GHz	类型	功能	应用场景	电流/功耗	封装	尺寸（mm*mm）	环保
SIV009SP4	23.5~27.5	VCO	窄带VCO	5G信号源	148mA	QFN-24L	4*4	RoHS√
SIV025SP4	27~30	VCO	窄带VCO	5G信号源	148mA	QFN-24	4*4	RoHS√
SIP012SP4	2~7	模拟移相器	180°连续移相	Massive MIMO、相控阵	1uA	QFN-24L	4*4	RoHS√
SIP017SP4	18~26.5	模拟移相器	360°连续移相	Massive MIMO、相控阵	1uA	QFN-24L	4*4	RoHS√
SIP051SP5	1.8~3.8	模拟移相器	360°连续移相	Massive MIMO、相控阵	10uA	QFN-32L	5*5	RoHS√
SIP052SP5	3~6	模拟移相器	360°连续移相	Massive MIMO、相控阵	1uA	QFN-32L	5*5	RoHS√
SIP054SP3	24.5~31	模拟移相器	360°连续移相	Massive MIMO、相控阵	1uA	QFN-16L	3*3	RoHS√
SIE055SP3	2~7	均衡器	电调均衡量	Massive MIMO、相控阵	10uA	QFN-16L	3*3	RoHS√

website: www.sicoresemi.com

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SIP052 Analog Phase Shifter – SPECS

电性能表（TA=＋25℃）

参数名称	最小值	典型值	最大值	单位
频率范围	3		6	GHz
移相范围	360	380		deg
插入损耗		3.5		dB
回波损耗（输入&输出）		15		dB
Vt端口电压	0		14	V
Vt端口电流			1	uA
相位误差		±5		deg
推荐输入功率			15	dBm
移相切换时间		250		ns
相位温度敏感度		0.12		deg/℃
移相灵敏度		26		deg/V

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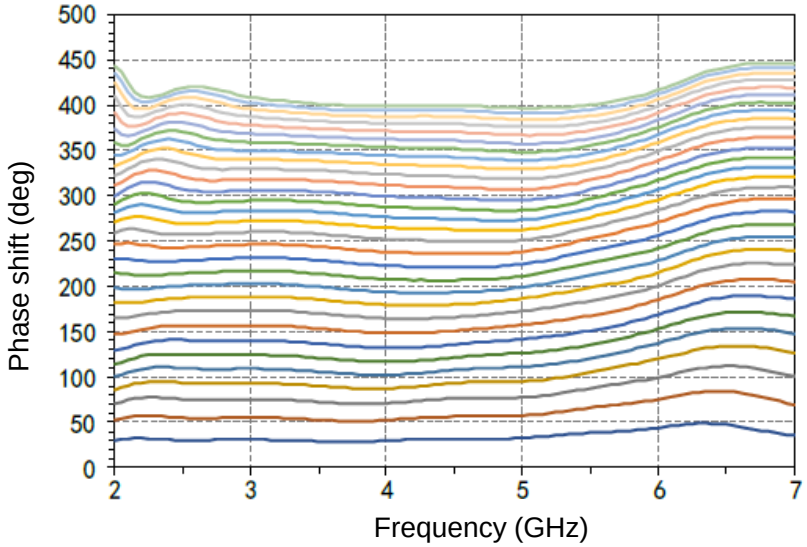
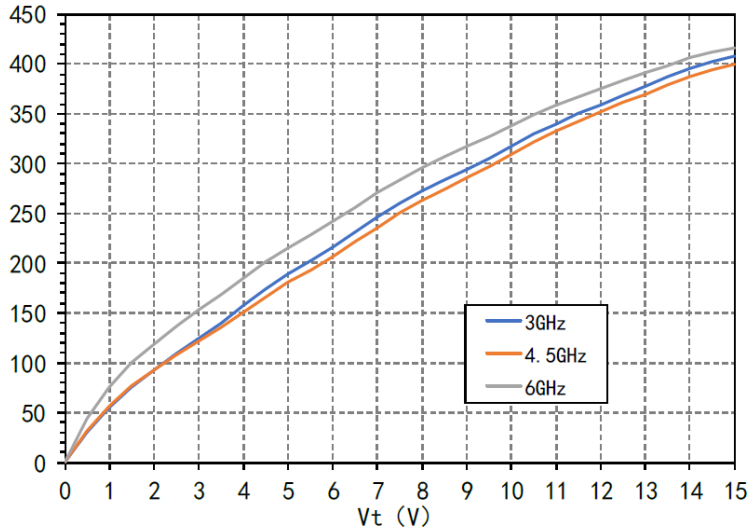
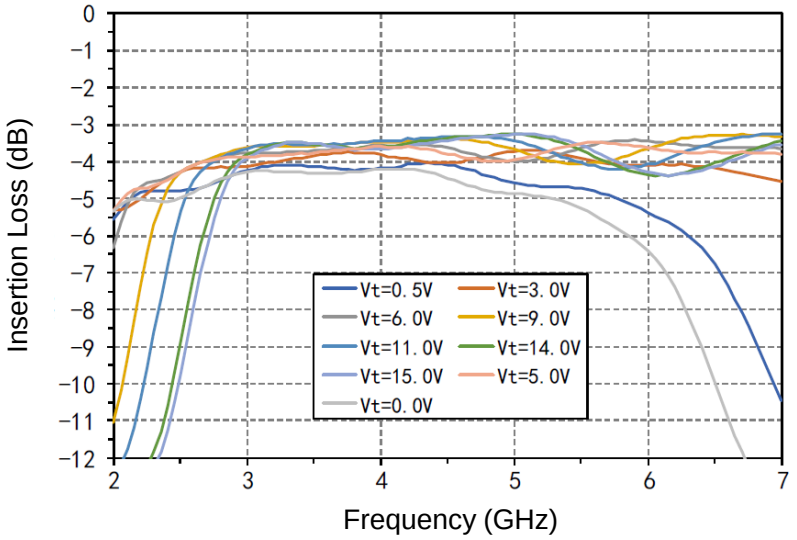
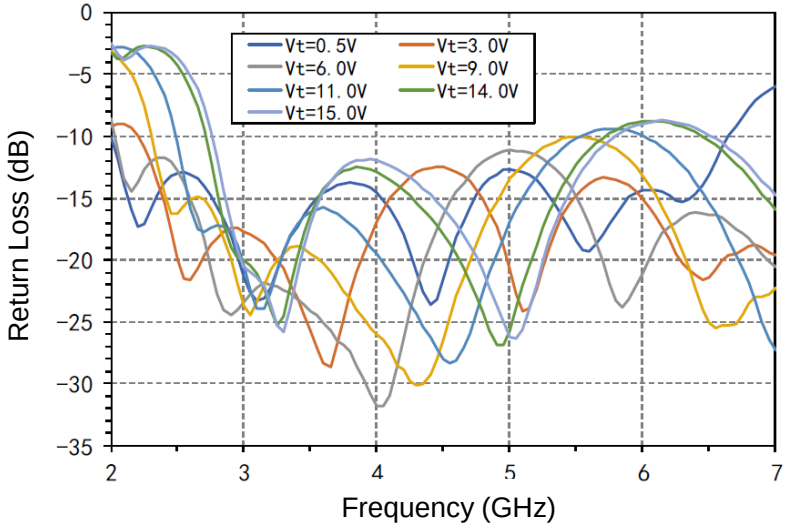
Measured Results









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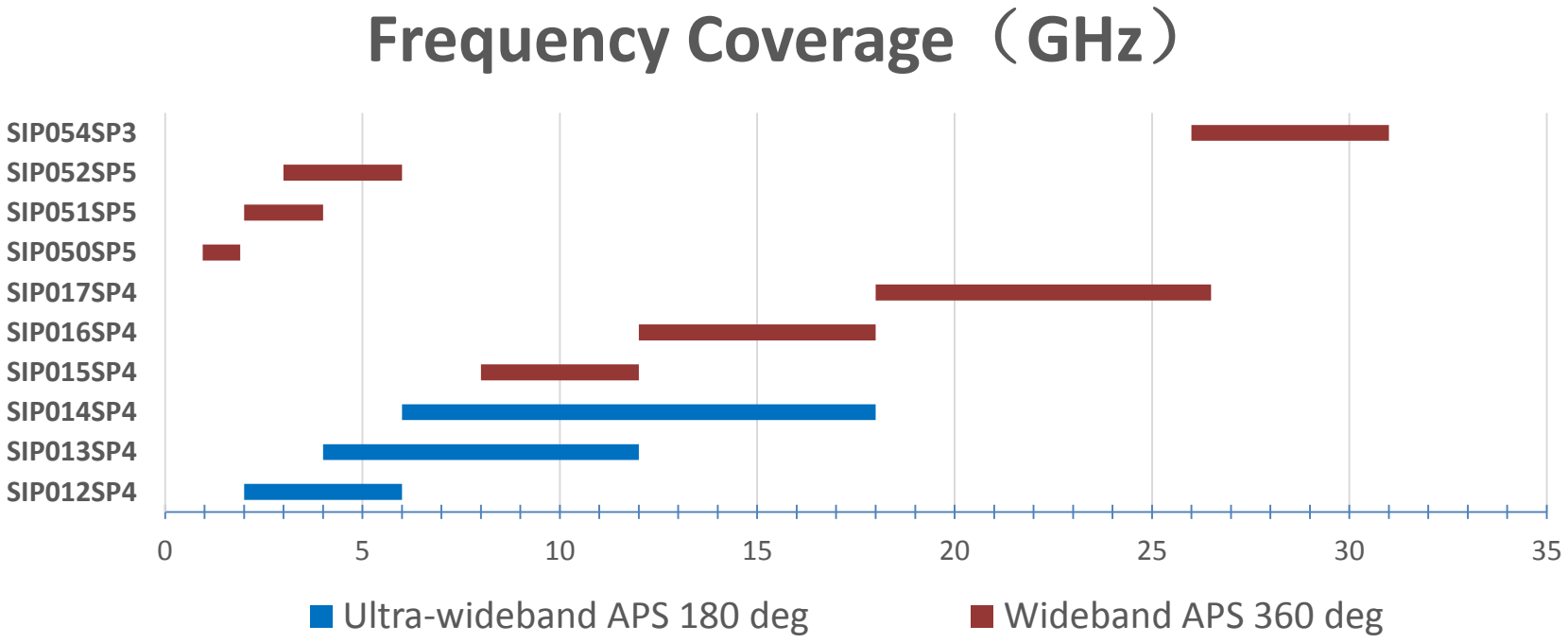
Analog Phase Shifter Product Line： 1 – 31.5GHz



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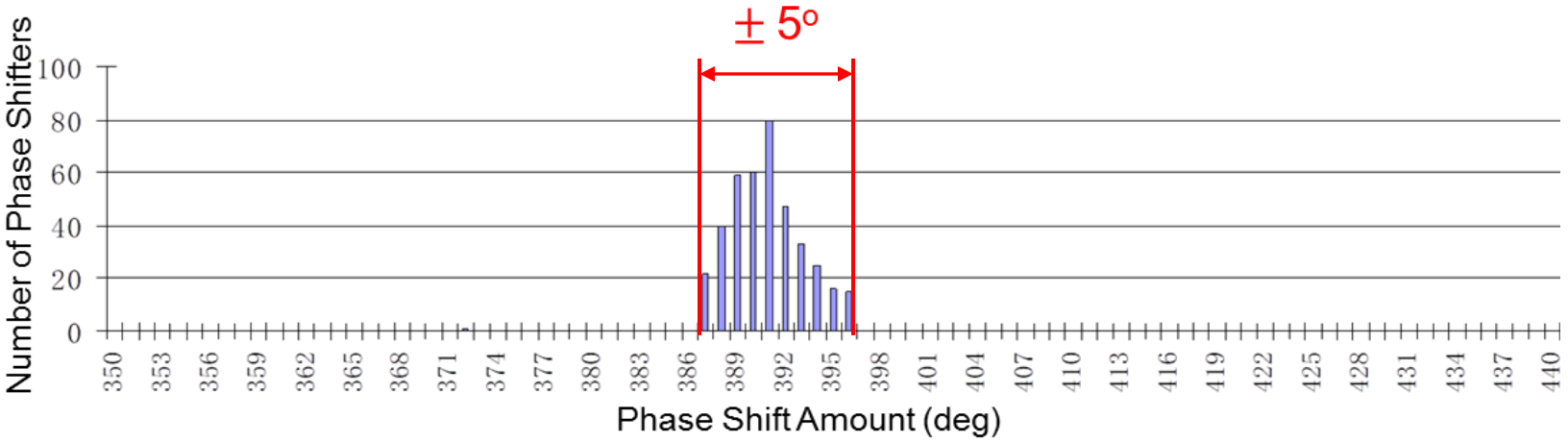
Measured Phase Shift Distribution



3-6GHz phase shift amount distribution from a same batch lot at Vt=14V.

Challenges:

- Meet **~1° accuracy** with ± 5° device phase distribution
- REF channel calibrated data can not directly apply to other channels
- Full calibration for each channel – **time, data space** consuming

  a cyclic convergence process using the regression algorithm to continuously adjust the phase and attenuation amount for each state of the channel.

Need for Innovated Channel Phase Calibration !

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Multi-channel Phase Calibration Steps

1. Reference channel – full calibration

2. Fast calibration for the rest channels based on REF channel calibrated data

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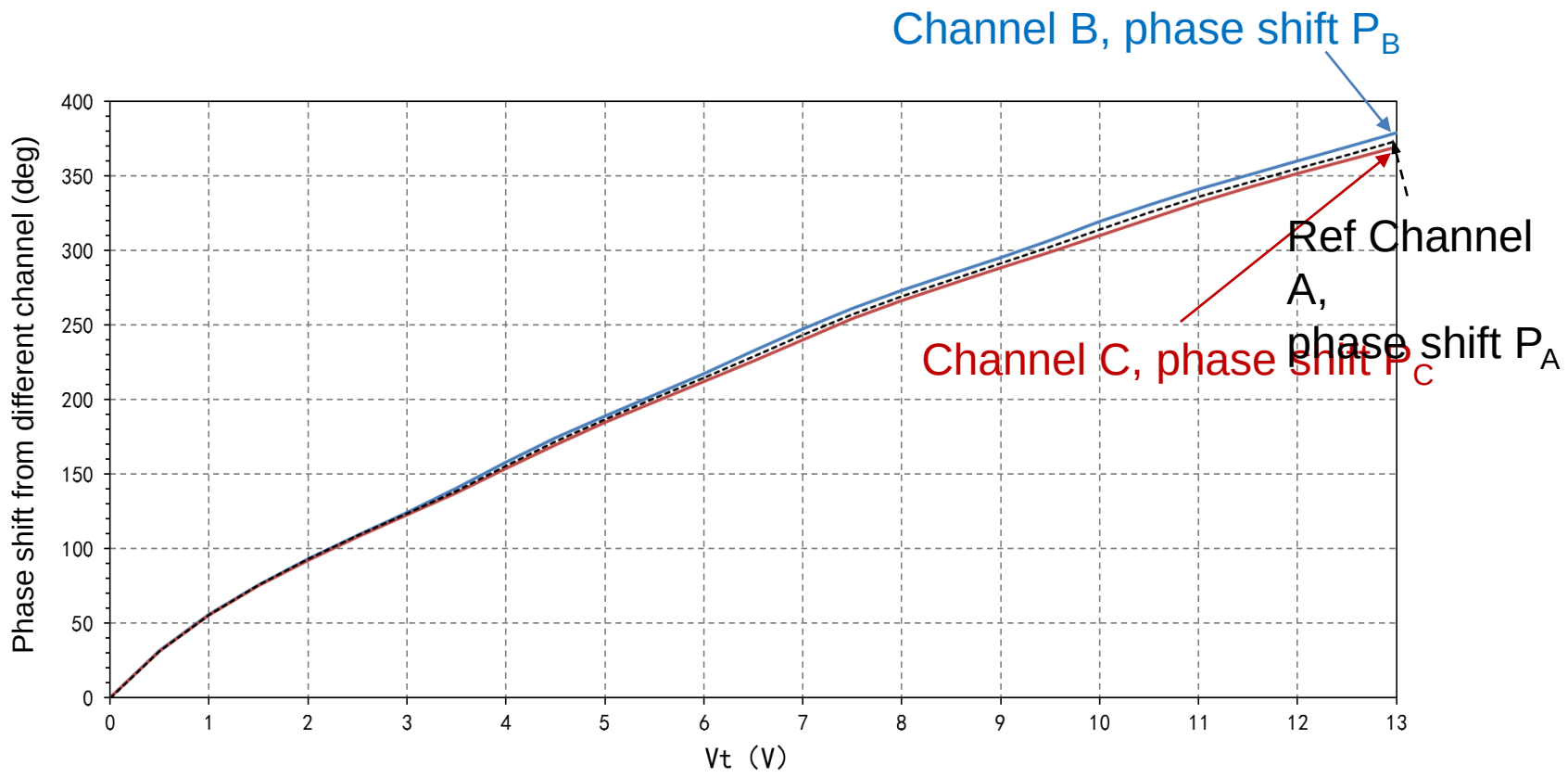
Phase shift vs. Vt - different channels @4.5GHz



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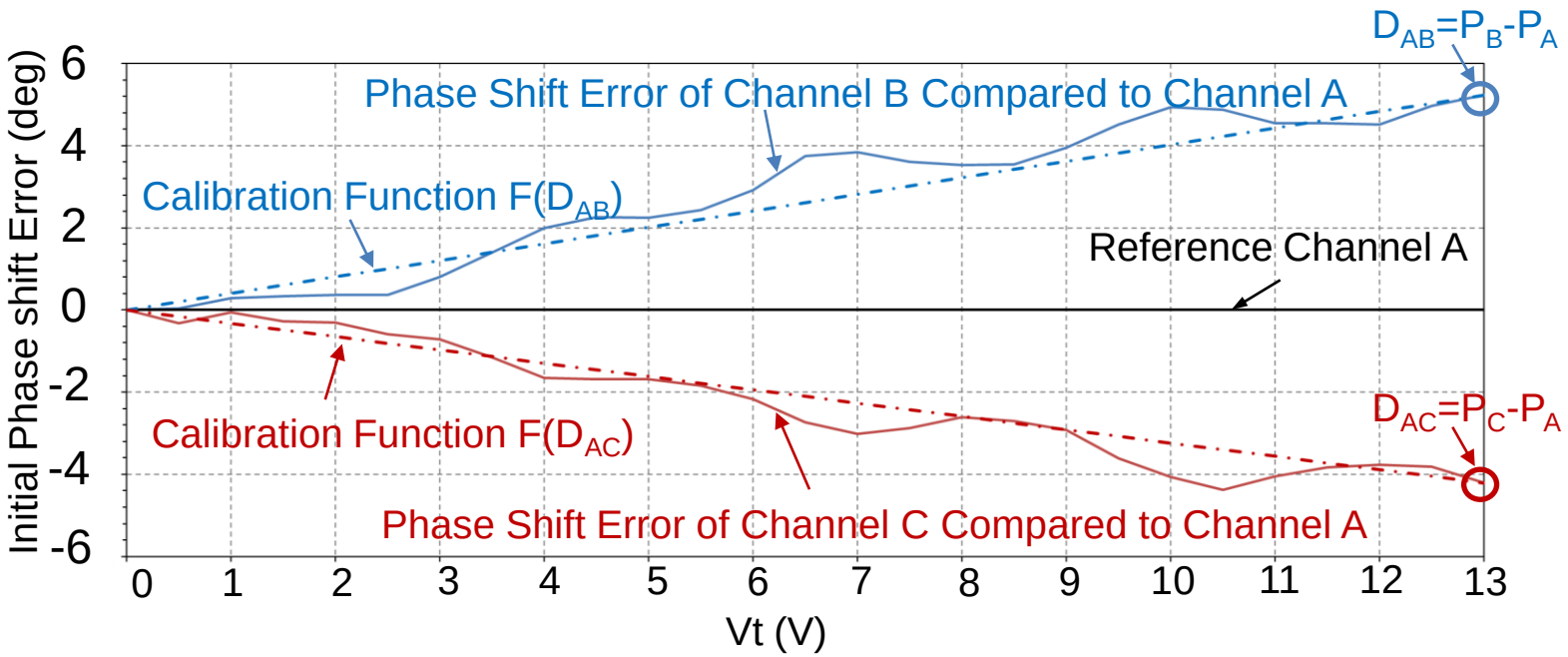
Channel Phase Calibration Steps @4.5GHz



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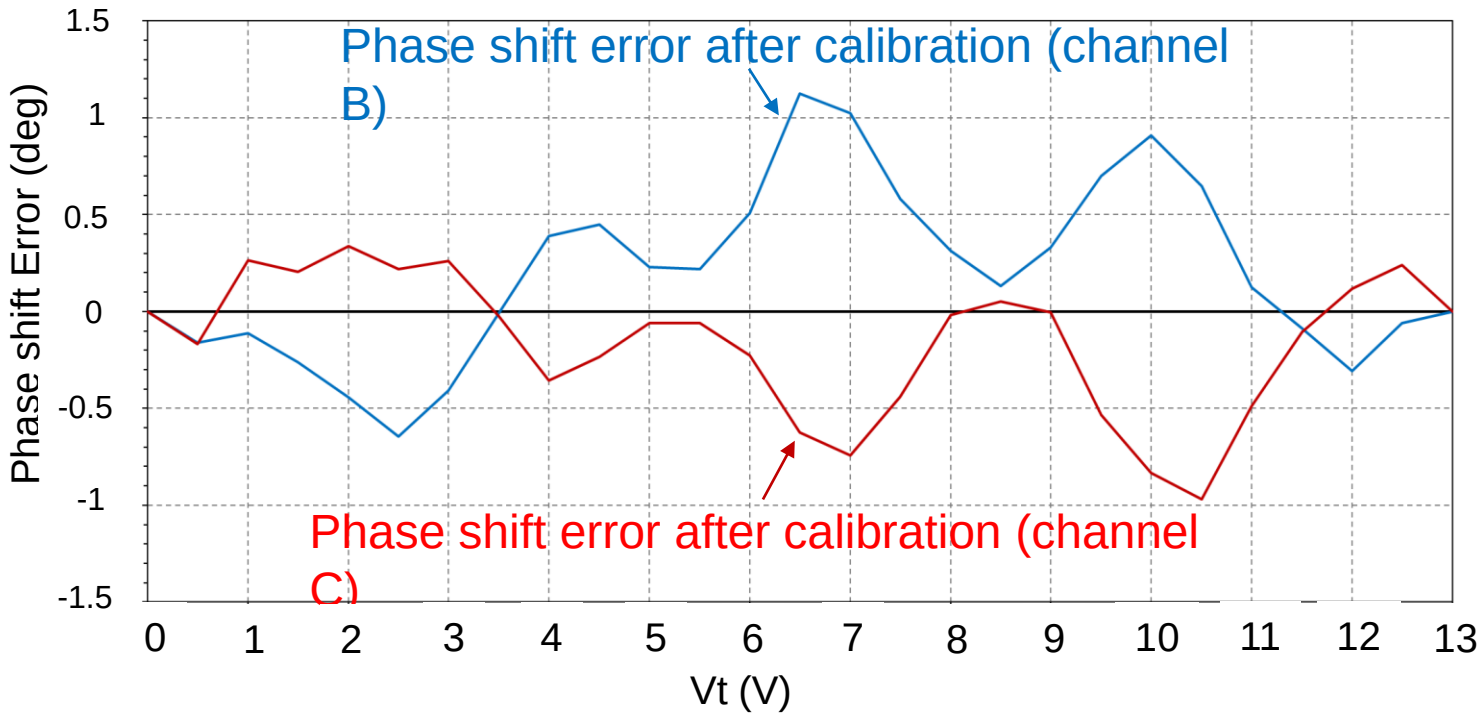
Phase shift error after calibration @4.5GHz



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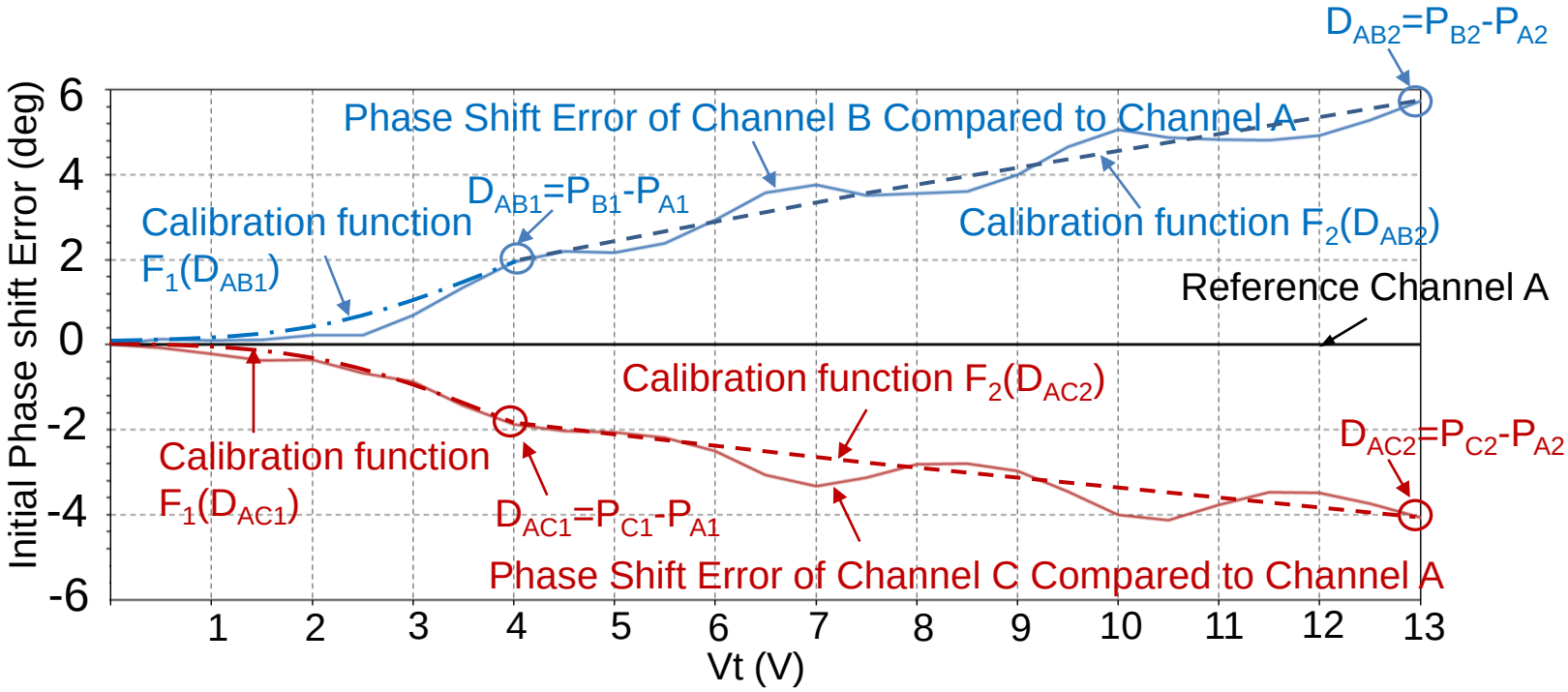
Channel Phase Calibration Steps: more sections/anchor points



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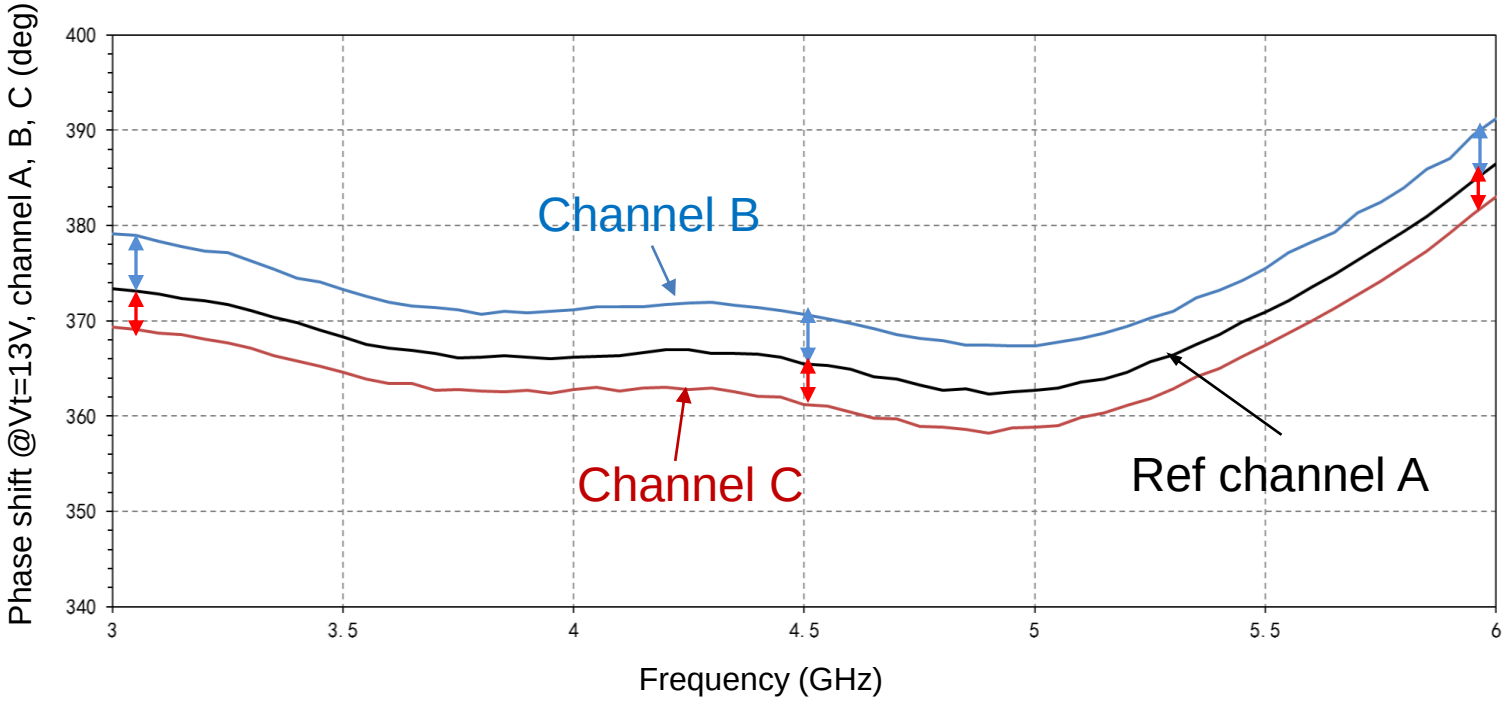
Phase Shift vs Frequency – different channel @Vt=13V



- Phase shift difference stays constant over frequency
- Calibrate at a single frequency (e.g. @4.5GHz), apply to full frequency band.

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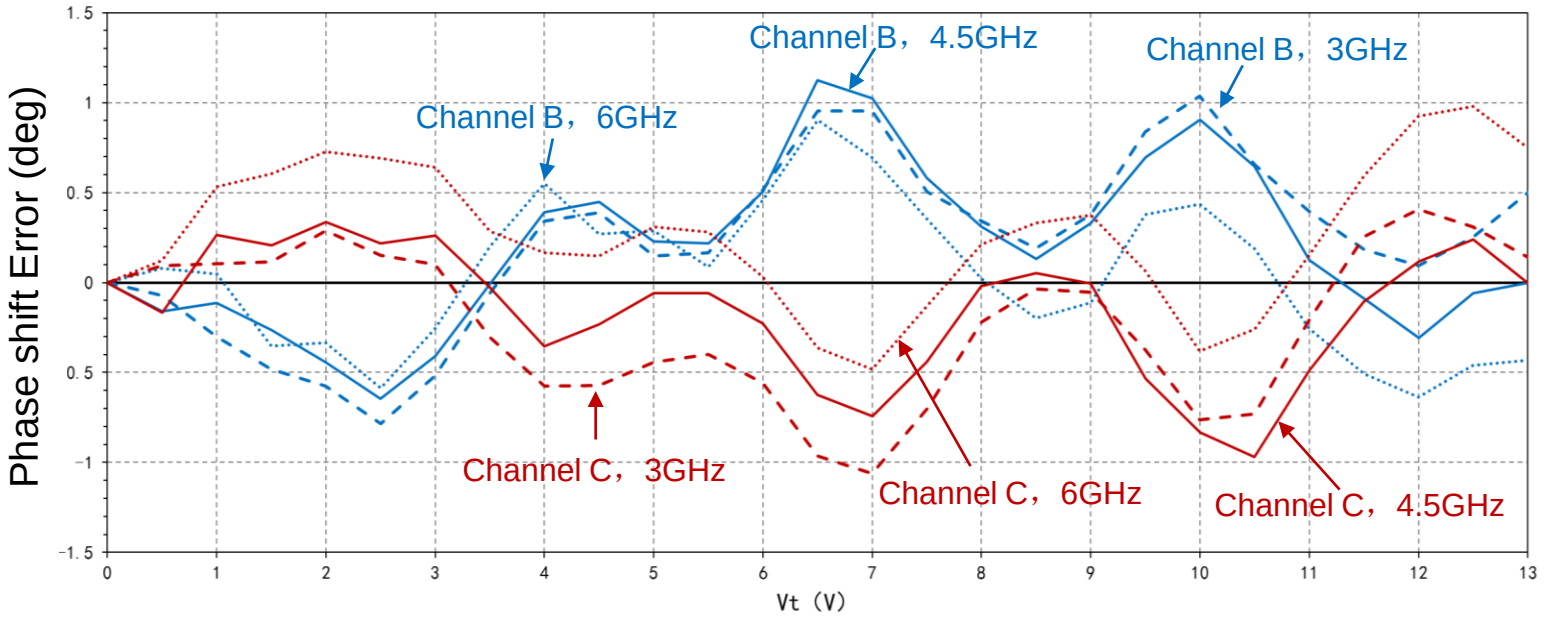
Phase shift error after calibration @3, 6GHz



Apply calibration function F(D) @4.5GHz to 3GHz and 6GHz, phase errors stay within ±1° as well

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Conclusions

- Proposed a novel phase calibration method for multi-channel 5G phased-array
- Achieved lowest time, data space consuming, while keeping precision of $<1^{o}$ over wideband
- Sicore's analog phase shifters are the best candidate for 5G phased array

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References

- B. Peterson et al., "5G Fixed Wireless Access Array and RF Front-End Trade-Offs", *Microwave Journal*, Feb. 2018.
- Microwave Journal webinar: Design Innovations in 5G mmWave FEMs and Phased Arrays
- SIP052SP5 product datasheet. [Online]. Available: http://www.sicoresemi.com.
- www.mitsubishielectric.com: Massive-element antenna systems technology for 5G base stations

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Thanks!

Q & A